7. GROUNDWATER RISK REGISTER

This section presents a register of risks to the groundwater posed by the construction and operation of the Fall Creek/White River CSO tunnel. This risk register is limited to those hazards and consequences associated with groundwater. In future phases of the project, a complete project risk register should be developed and continually updated and managed throughout design and construction of the facilities.

A project risk register is an increasingly common tool that is used for large, complex construction projects to clearly define and identify hazards, their causes and potential consequences to projects. The project risk register also presents how those hazards may be mitigated and managed through the planning, design and construction process. As identified in the Fall Creek Evaluation Study Report (Black & Veatch, 2005), the primary risks to groundwater include:

- Exfiltration or potential groundwater quality impacts on nearby public and private water supply wells
- Excessive groundwater infiltration during construction
- Depletion of groundwater resources
- Excessive groundwater infiltration during operation, thereby reducing available capacity and increasing treatment costs
- Impact of pre-excavation grouting on existing wells

These primary risks to the groundwater along with the construction methodology assumptions presented in the Fall Creek Evaluation Study Report (i.e. main beam hard rock tunnel boring machine with cast-in-place tunnel lining) were used as a baseline and expanded to develop the groundwater risk register. The register identifies groundwater hazards to the project associated with regulatory approvals and permits, stakeholder concerns, design and contractual issues, construction, and safety. The risk register is presented as one (1) comprehensive spreadsheet with two (2) distinct sections (Appendix B). The first section is primarily associated with hazard identification and an initial risk assessment, which has been completed based upon the efforts conducted to date. The second section addresses risk management and includes defined action items, and reassessment of the risk once the action

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items have been completed. It is recommended that this section of the register be completed and updated throughout design in conjunction with future project phases.

The following definitions are applicable to this risk register:

- Hazard – An event impacting a project that could pose a risk with negative consequences.
- Risk - The product of the likelihood of a hazard's occurrence and severity of its consequences.

7.1 HAZARD IDENTIFICATION AND INITIAL RISKS

The four (4) primary stages of the hazard identification and initial risks of the register are described below:

- Hazard Identification - This is best accomplished by a core team of risk and subject-matter experts creating a "seed list" of hazards, the cause thereof, and their potential consequences followed by a workshop to obtain stakeholder agreement.
- Risk Probability - The chance of risk measured on a scale of 1 to 5 (1 being lowest and 5 being highest) by using probability ratings as identified in Table 7.1.
- Risk Consequence – The rating is determined on a scale of 1 to 5 (1 being lowest and 5 being highest) based on the criterion being considered and its relationship to the hazard identified. Table 7.2 identifies considerations for risk analysis rating scales compared to the criterion. Stakeholder consensus of the risk analysis rating scales is critical for the project risk register. It is also important that these rating scales are not altered for the duration of the project.
- Risk Score - The calculation of the risk is displayed as the risk score for the probability of each consequence. The risk score is determined by multiplying the risk probability rating by the highest identified risk consequence rating. It should be noted that a single hazard can be caused by several different

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factors and have different consequences. The risk score matrix is included as Table 7.3, and is color coded to signify higher levels of risk.

An example of the determination of a risk score is presented as Table 7.4. Based on the Hazard Identification, the risk probability (A) and risk consequence (B) is determined. The risk score ($C=AxB^H$) is calculated by multiplying the risk probability (A) by the highest risk consequence (B^H).

This section of the register, as indicated in the example table, displays risks associated with the project without any future mitigating measures having been implemented. It is important that this exercise be carried out with no mitigating measures so that the impact of any measure taken can be fully evaluated.

The first section of the groundwater risk register for the project is summarized in Table 7.5 and included as part of the overall risk register in Appendix B.

Table 7.1
Risk Probability

Probability Rating Scale	
5	Probable
4	Likely
3	Possible
2	Unlikely
1	Improbable

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Table 7.2
Risk Consequence

Risk Consequence Criterion	Consequence Rating				
	Low				**High**
	1	**2**	**3**	**4**	**5**
Financial *(Estimated Range)*	Less than $100k	$100k - $750k	$750k - $2 million	$2 million - $10 million	Greater than $10 million
Project Schedule Impacts	1 to 7 days	7 to 21 days	21 to 90 days	3 to 9 months	9 months to 1 year or more
Social Environment	Complaints from local public	Inquiry from local officials / politicians	Complaints from local officials / politicians	Major local impact or minor national impact	National and international adverse coverage or impacts
Regulatory/ Legal	Isolated non-compliance	Potential non-compliance with potential for third-party claims	Systematic non-compliance with potential for fines or third party claims less than $100k	Systematic non-compliance with potential for fines or third party claims greater than $100k	Non-compliance with potential for significant implications for senior personnel and potentially large damages
Health & Safety	Minor injury or near-miss (non-reportable)	Minor injury (reportable)	Major injury and/or multiple minor injuries, including minor traffic accidents–public	Multiple major injuries, minor injury to public	Significant injury to public or any fatalities
Operating and Maintenance	Minor increase in expected O&M activity (barely measurable)	Measurable increase in expected O&M activity	Major increase in O&M activity or any shutdown not requiring access to tunnel	Planned shutdown of tunnel for 3 to 6 months or any unplanned shutdown involving surface work	Unplanned loss of service or shutdown requiring access to tunnel, or catastrophic loss of service to tunnel or valves
Natural Environment	Minor short term local impact	Major short term local impact	Short term regional impact	Long term local impact	Long term regional impact

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Table 7.3
Risk Score Matrix
(Probability X Consequence)

Risk Consequence From Table 7.2	1	2	3	4	5
5	5	10	15	20	25
4	4	8	12	16	20
3	3	6	9	12	15
2	2	4	6	8	10
1	1	2	3	4	5

Risk Probability From Table 7.1

Legend
White – Low Risk
Yellow – Intermediate Risk
Red – High Risk

Table 7.4
Example Format and Use of Risk Register

Hazard	Cause of Hazard	Potential Consequence	Risk Probability (A)	Risk Consequence (B)						Risk Score ($C=AxB^H$)
				Financial	Project Schedule	Social Environment	Regulatory/Legal	Health and Safety	Natural Environment	
Problems with pre-excavation grouting	Grouting affects well field production yields	Individual wells shut down, require replacing	3	3	3	4 (B^H)	4			12

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7. GROUNDWATER RISK REGISTER

INSERT TABLE 7.5

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7.2 RISK MANAGEMENT AND MITIGATION

The second section of the risk register forms the risk management and mitigation actions. In this section the concern is not the unmitigated risk, but residual risk after some actions are taken. Managing the risk using the register is an iterative process of action, measurement, reassessment, and identification of further action if necessary. For the duration of the project, the existing residual risk is the measure of the current project risk profile. Managing each risk using the register is carried out as follows:

- Identification of mitigation measures and which individual should carry them out and by what date.
- Implementation of mitigation measures and information to make sure that they can be adequately measured, and that their mitigating impact can be properly assessed.
- Reassessment of the hazard and consequence, but only the measures in place are considered so the risk register is not “aspirational” to the measures that will be implemented. This prevents a false measure of the risk profile from being projected.
- Update register and recalculate the risk profile. This is achieved by ranking the hazards in decreasing order so that the highest scoring and most critical risks rise to the top of the register.

7.3 RISK REGISTER APPLICATION

The most important factor to recognize is that the risk register is a dynamic document. This document should be expanded to identify and manage all known project risks during planning, design and construction. It needs to be updated frequently and used as a checklist of risk mitigation action items.

During design, the risks identified for the project should be assessed for their potential cost or schedule impact and their likelihood of occurrence. These assessments are provided with dollar values, time periods, and probabilities of

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occurrence. After in-depth consideration and a credibility check of the inputted data, a Monte Carlo simulation should be completed to provide a representative distribution of the overall likelihood of a certain cost or schedule delay. These values are important as they give a good indication of the contingency or allowable schedule slippage to include in budgets for the construction phase of the project.